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Regional scale assessment of soil predictors of groundwater phosphate (P) levels in acidic sandy agricultural soils

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Possible factors affecting the leaching of P to the groundwater in the Belgian sandy area are examined via regression analysis. The main objective is to investigate the dependency of phreatic groundwater phosphate concentrations (Flemish VMM monitoring net, monitoring period 2010-2013) on soil phosphate saturation degree (PSD) (1994-1997 mapping for Flemish Land Agency) (n = 1032). Additionally explored parameters include: depth distributions of Fe- and Al-oxides, sorbed P and phosphate sorption capacity (PSC) and soil pH. Interpolated data of these soil parameters in 3 depth layers (0-30, 30-60, 60-90 cm) were generated by ordinary kriging. Secondly, we assessed the significance of other edaphic factors potentially controlling the groundwater P: topsoil organic carbon content (OC %), soil clay content and fluctuation of the groundwater table.

Overall, the mean PSD halved with each 30 cm depth layer (56 > 24 > 13 %) and was correlated to groundwater PO_4^{3-} level. The statistical significance of the correlation with groundwater PO_4^{3-} concentrations increased with depth layer. The poor correlation (R^2 = 0.01) between PSD and groundwater phosphate concentration indicates that many factors, other than soil P status, control the transport of P from soil solution to the groundwater in Belgian sandy soils.

A significant (P<0.01) positive non-linear relationship was found between groundwater PO_4^{3-}concentration and pH_{KCl} in all three studied depth layers, again increasingly with depth. Within the pH range of the 30-60 cm layer (pH_{KCl} 4.0-5.7) PO_4^- solubility should increase with pH. Elevated soil OC levels surprisingly co-occurred with low groundwater PO_4^{3-} concentrations (r = -0.18, P<0.01, n = 191). Groundwater PO_4^{3-} was furthermore significantly and positively correlated to clay % in both the 0-15 cm (r = 0.15, τ = 0.25, P<0.01, n = 1032) and 60-90 cm (r = 0.13, τ = 0.20, P<0.01, n = 1032) depth increments. These positive correlations were unexpected and could be indirect through mutual relations with groundwater level. Indeed, a shallower groundwater level (MHL or MLL) corresponded with higher phosphate concentrations (r = -0.126, τ = -0.107, P<0.01, n = 1028). The shortened distance between 0-90 cm soil PO_4^- and the groundwater logically explains this positive relation. In sum, factors other than soil P status more strongly determine groundwater PO_4^- concentrations but extensive observational datasets are much needed to unravel such indirect mediating effects of edaphic parameters. Structural equation modeling for example could be used to understand the practical importance of individual soil, management and hydrological potential predictors of groundwater PO_4.